PATENT ABSTRACTS OF JAPAN

(11)Publication number : 2001-035697
(43)Date of publication of application : 09.02.2001

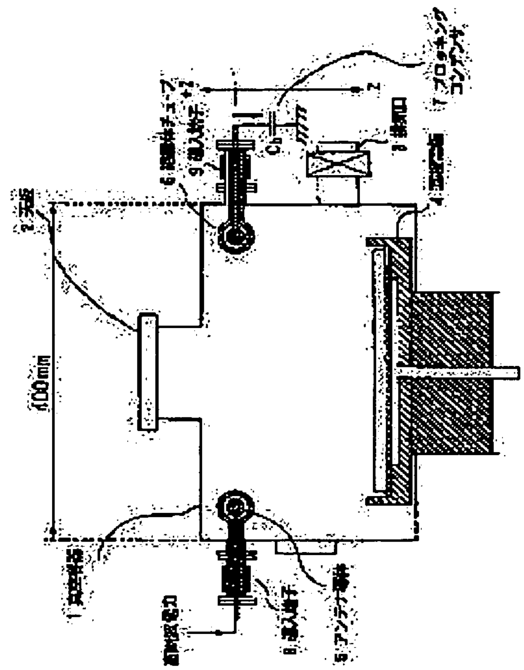
(51)Int.Cl. H05H 1/46
H01L 21/3065

(21)Application number : 11-212238
(22)Date of filing : 27.07.1999

(71)Applicant : JAPAN SCIENCE & TECHNOLOGY CORP
(72)Inventor : MIYAKE MASAJI
SHIYOUJI TATSUO
SETSUHARA YUICHI

(54) PLASMA GENERATOR

(57)Abstract:
PROBLEM TO BE SOLVED: To eliminate the limitation of the shape, bore and length of a discharge chamber by installing an antenna itself for plasma generation purpose in a vacuum container and to stably generate large-size, large-volume and high- density plasma by coating all surface of an antenna conductor with an insulator.
SOLUTION: A whole antenna conductor 5 is put in a vacuum container 1 for a plasma generator, eliminating the need for a barrier rib and a top plate of an insulator to permit the effective use of all induced field emitted from an antenna. The inductance of the antenna is made smaller or the antenna conductor 5 is coated with an insulator, whereby abnormal discharge is restricted, resulting in stable high-density plasma.



LEGAL STATUS

[Date of request for examination]	24.07.2002
[Date of sending the examiner's decision of rejection]	
[Kind of final disposal of application other than the examiner's decision of rejection or application converted registration]	
[Date of final disposal for application]	
[Patent number]	
[Date of registration]	
[Number of appeal against examiner's decision of rejection]	

CLAIMS

[Claim(s)]
[Claim 1] The plasma generator characterized by installing the antenna which impresses high-frequency power and is made to generate induction field in the plasma generator of the inductive-coupling method by high frequency discharge in a vacuum housing.
[Claim 2] The plasma generator characterized by putting all the front faces of an antenna to a vacuum in the plasma generator shown in claim 1.
[Claim 3] The plasma generator characterized by covering all the front faces of an antenna with the insulator in the plasma generator shown in claim 1.
[Claim 4] It is the plasma generator characterized by consisting of linear conductors which carry out termination without an antenna's going around in the plasma generator shown in claim 1.
[Claim 5] It is the plasma generator characterized by an antenna consisting of linear conductors of the typeface of at least one or more KO, or a radii form in the plasma generator shown in claim 1 thru/or claim 4.
[Claim 6] The plasma generator characterized by arranging the linear conductor which forms the frame of the typeface of two KO which constitutes an antenna, or a hemicycle in the plasma generator shown in claim 5 in accordance with the wall of a vacuum housing.
[Claim 7] at least one or more shape of a straight line by which the antenna is arranged in accordance with the wall of a vacuum housing in the plasma generator shown in claim 1 thru/or claim 4 -- it constitutes from a conductor -- having -- these shape of one or more straight line -- the plasma generator characterized by supplying the high frequency current to juxtaposition to each of a conductor.
[Claim 8] in the plasma generator shown in claim 1 thru/or claim 4, an antenna consists of ring-like conductors -- having -- the shape of this ring -- one with a conductor -- this -- for other one point which counters one point on a diameter line -- the shape of a ring -- the plasma generator characterized by supplying the high frequency current to a conductor.
[Claim 9] The plasma generator characterized by forming the field generating means which makes a plasma consistency uniform in the outside of a vacuum housing in the plasma generator shown in claim 1 thru/or claim 4.
[Claim 10] The plasma generator characterized by electric capacity inserting immobilization or an adjustable capacitor between the node of the earth side of an antenna, and touch-down in the plasma generator shown in claim 1 thru/or claim 4.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention supplies the high frequency current to an antenna, generates high frequency electric field, generates the plasma by the electric field, is concerned with a plasma generator useful to the plasma treatment equipment which carries out surface treatment, such as etching and thin film formation, to a substrate side, and is suitable for processing large area substrates, such as a glass substrate for liquid crystal, especially.
[0002]
[Description of the Prior Art] In the field of the processor using the plasma of the dry etching system used by the production process of a semiconductor device or a liquid crystal display, an ashing device, plasma-CVD equipment, etc., etc., diameter-ization of macrostomia is demanded also for the source of the plasma of a processor with enlargement of a processing substrate in recent years. Moreover, on the other hand, in order to secure an etching rate, a membrane formation rate, and a throughput, the densification of the plasma under a high vacuum is demanded.
[0003] Among these, in order to promote the excitation efficiency of the plasma about the densification of the plasma, the method of using a RF and generating inductively coupled plasma (Inductively Coupled Plasma, Following ICP and an abbreviated name) is adopted. ICP can make the coil for antenna excitation mainly able to generate induction field for the high frequency current in a vacuum by the sink and this, can generate the plasma, and can generate the high density plasma to homogeneity under a high vacuum.
[0004] One example of the plasma treatment equipment using the conventional ICP is shown in drawing 12 . The vacuum housing to which 21 performs etching processing of a substrate etc. in drawing 12 (process chamber), Insulator septa, such as a quartz with which 22 was prepared in a part of vacuum housing, the RF antenna of the circumference configuration which has the number of turns of 1 or more ******s in which 23 was prepared the shape of a loop formation, and in the shape of a spiral along with the wall surface by the side of the atmospheric air of the insulator septum 22, The discharge room where, as for the RF generator by which 24 supplies high-frequency power to a RF antenna, and 25, an exhaust port is generated, and, as for 26, the discharge plasma is generated, and 27 are substrate electrodes.
[0005] However, if it is going to diameter[of macrostomia]-ize the path of the discharge room 26 more than 400mmphi, in order to obtain the mechanical strength which is needed for resisting the differential pressure of the open air under atmospheric pressure, and the discharge interior of a room under a high vacuum by the conventional method of drawing 12 The induction field reinforcement which must make thickness of the insulator septum 22 the thickness of no less than 10-30mm, and is emitted from the RF antenna 23 for this reason There were problems, like decrease exponentially and discharge effectiveness worsens as it becomes far from an antenna, the inductance of an antenna 23 becomes large, and the high-frequency voltage generated at an antenna becomes high.
[0006] Instead of forming an antenna so that the side face of a discharge room may be made to go around in this way on the other hand, the discharge room top face of a vacuum housing was used as the top plate of an insulator, and there was also a method which installs an antenna in the outside. However, by this method, when the thickness of the insulator of the top plate of the thing of 300mmphi tended to diameter[of macrostomia]-ize the diameter of a discharge room to being about 20mm more than 400mmphi, in order that the diameter of a discharge room in the present condition might secure a mechanical strength, there was a problem that the

thickness of no less than 30-50mm was needed.
[0007]
[Problem(s) to be Solved by the Invention] In the conventional inductive-coupling mold plasma generator which installs a RF antenna in the wall surface by the side of the insulator septum of a vacuum housing, or the atmospheric air of a top plate The thickness of an insulator must be sharply increased as the path of a discharge room becomes large. Moreover, since only the induction field component emitted to the field side which touches the insulator septum or top plate of a vacuum housing among the induction fields emitted from an antenna was used for maintaining a discharge, there was a problem that the use effectiveness of the high-frequency power switched on was bad.
[0008]
[Means for Solving the Problem] In order to solve the above-mentioned trouble, in the plasma generator by this invention, install the antenna itself in the location of the arbitration inside a vacuum housing, that is, make it an internal antenna, and it is made for all the front faces of an antenna to be in a vacuum, and while enabling it to use effectively all the induction fields emitted from an antenna, the need using the septum and top plate of an insulator is abolished. Moreover, if the big electrical potential difference at an antenna is impressed to coincidence by this invention in the case of an internal antenna, since it will become easy to produce abnormality discharge, the inductance of an antenna is made small as much as possible, and it is considering as the structure which 1 or more ******s of antennas do not go around at least. Below, the principle of this invention is explained in full detail.
[0009] Since the antenna itself is put to the plasma when an antenna is introduced in a vacuum chamber, ion and an electron flow into an antenna depending on the electrical potential difference impressed to an antenna. Since the passing speed to the RF electromagnetic field of the ion and electron in the plasma differs greatly at this time, in a time average, the electron in the plasma flows into an antenna superfluously effectually, and plasma potential rises. consequently, the densification of the plasma by the increment in injection high-frequency power -- following -- an antenna -- the rise of the plasma potential by the electrostatic coupling with a conductor becomes remarkable, and abnormality discharge is caused in a vacuum housing. Thus, with the ICP plasma of an internal antenna mold, there is a problem of being hard to acquire the stable high density plasma. Moreover, the increment in an electrostatic coupling enlarges the amplitude of the high-frequency voltage impressed to the plasma through a sheath from an antenna. Increase of the amplitude of high-frequency voltage induces the turbulence of the plasma (increase of RF fluctuation of plasma potential). Consequently, fluctuation of the plasma at the time of etching or thin film formation becomes large (for example, increase of ion incidence energy), and we are anxious about the effect of a plasma damage. Therefore, in the ICP plasma production of an internal antenna mold, the reduction in the operating voltage of the high-frequency voltage to impress is important, and, for that purpose, inductance reduction of an antenna and control of an electrostatic coupling are required.
[0010] For this reason, in this invention, it is characterized by installing the antenna itself in the location of the arbitration in a vacuum housing so that it may describe at claim 1. It becomes possible to generate the high density plasma of the diameter of macrostomia, without being restricted to the configuration, aperture, and die length of a discharge room by this.
[0011] Moreover, in this invention, it is characterized also by putting all the front faces of the antenna concerned to a vacuum so that it may describe at claim 2.
[0012] in order to control the increment in the electrostatic coupling accompanying the formation of an internal antenna by this invention furthermore so that it may describe at claim 3 -- an antenna -- it is characterized also by covering all the front faces of a conductor with an insulator.
[0013] Furthermore, by this invention, in order to control the increment in the inductance accompanying enlargement of an antenna so that it may describe at claim 4, it is characterized by constituting an antenna from a linear conductor which carries out termination without going around.
[0014] Furthermore, by this invention, it is characterized also by aiming at reduction in an inductance by constituting an antenna from a linear conductor of the typeface of at least one or more KO, or a radii form so that it may describe at claim 5.
[0015] Furthermore, by this invention, an antenna is characterized also by taking the structure which arranges the linear conductor which forms the frame of the typeface of two KO, or a hemicycle in accordance with the

wall of a vacuum housing so that it may describe at claim 6.
[0016] at least one or more shape of a straight line which has furthermore arranged the antenna in accordance with the wall of a vacuum housing by this invention so that it may describe at claim 7 -- a conductor -- constituting -- these shape of one or more straight line -- it is characterized also by supplying the high frequency current to juxtaposition to each of a conductor.
[0017] furthermore, this invention describes to claim 8 -- as -- an antenna -- a ring-like conductor -- constituting -- the shape of this ring -- one with a conductor -- this -- for other one point which counters one point on a diameter line -- the shape of a ring -- it is characterized also by supplying the high frequency current to a conductor.
[0018] Furthermore, by this invention, it is characterized by attaching the permanent magnet of a multi-cusp mold in accordance with the outer wall of a vacuum housing so that it may describe at claim 9, and the consistency of the plasma in a vacuum housing may become uniform.
[0019] Furthermore, by this invention, in order to control the high-frequency-voltage increase by large power injection so that it may describe at claim 10, when electric capacity inserts immobilization or an adjustable capacitor between the termination of an antenna, and touch-down, it is characterized by reducing by half the airraid high-frequency voltage generated at an antenna.
[0020] Drawing 1 explains the basic configuration of the plasma generator by this invention. In addition, although the configuration of 1 example equipment of this invention is shown in drawing 1 for convenience, this invention is not limited to this.
[0021] the antenna according [accord / an exhaust port and 4 / a substrate electrode / on drawing 1 and / 1 / 2 / a vacuum housing (process chamber) and / 5] to this invention in a top plate and 3 -- a conductor and 6 -- an antenna -- the insulator tube which covers all the front faces of a conductor 5, and 7 -- an antenna -- the capacity which makes a conductor 5 float from touch-down (floating) -- immobilization or an adjustable blocking capacitor, and 8 and 9 -- an antenna -- while supporting a conductor 5 -- an antenna -- it is the introductory terminal which supplies high-frequency power to a conductor 5.
[0022] an antenna -- 1 by which the conductor 5 has been arranged along with the internal surface of a vacuum housing 1 although only the cross section was shown by a diagram the line of various configurations, such as a typeface of KO more than **, or a radii form, -- it consists of conductors. those lines -- each conductor is built by the die length which carries out termination without going around the die length which does not go the internal surface of a vacuum housing 1 around, i.e., an internal surface. Specifically, the pattern of an antenna as shown in drawing 3 , drawing 9 , drawing 10 , and drawing 11 etc. is applicable.
[0023] Since the whole antenna for plasma excitation is held in the vacuum housing 1, it is not necessary to form a part of vacuum housing with a thick insulator ingredient, and diameter[of macrostomia]-izing of equipment is easy, and a configuration change of an antenna can also be made arbitrarily and easily.
[0024] illustration -- like -- the inside of a vacuum housing 1 -- an antenna -- electrical potential difference which generates at an antenna the electrical potential difference (Vsheath) impressed to the sheath field of the plasma as shown in the equal circuit of drawing 2 when all the front faces of a conductor 5 are covered by the insulator tube 6 (Vantenna) A part for the fall of potential in an insulator (Vinsulator </SUB>) It can use and can express like a degree type.
Vsheath=Vantenna -Vinsulator =Vantenna Zsheath/(Zinsulator +Zsheath) (1)
It is Zinsulator here. And Zsheath shows the impedance of an insulator and a sheath field. These impedances mainly consist of a resistance component and an electrostatic-capacity component. When high-frequency power is increased and the consistency of the plasma increases, Zsheath decreases to the increment (notes: electrostatic capacity of sheath is inversely proportional to thickness of sheath.) sake in the electrostatic capacity by reduction of the equivalent resistance in the plasma (resistance component), and the fall of the thickness of a sheath. (Notes: In order that electrostatic capacity may carry out the electrostatic-capacity component of an impedance proportionally [inverse number], the increment in electrostatic capacity of a sheath contributes to reduction in an impedance.) Zinsulator is not concerned with the plasma state to this, but according to a fixed thing, the value of Vsheath becomes small, so that a plasma consistency becomes high. Thus, by covering an antenna front face with an insulator, the electron flow close to an antenna is intercepted and the electrostatic-coupling component of an antenna and the plasma is controlled. Consequently, rapid increase of the plasma potential accompanying the densification of the plasma is controlled, and the high density plasma production

stabilized without causing abnormality discharge becomes possible. Moreover, when sheath potential becomes small, sputtering to the vacuum housing wall and antenna by the plasma is controlled, and impurity mixing into a base material front face or a thin film can be reduced.
[0025] Let it be requirements to have the thermal resistance which does not produce a problem even if what it has a sufficiently (for example, single or more figures) larger impedance than the equivalent impedance of a sheath for (Zinsulator >>Zsheath) is required and is further put to the plasma directly in the quality of the material of an insulator, and selection of thickness, chemical stability, a mechanical strength, electric insulation, etc. For this reason, thickness should just be about 2-4mm with the quality of the material of the ceramic dielectric group which can fill high resistance, such as high purity alumina, a quartz, and a zirconia, high insulation, and a low dielectric constant to coincidence, for example.
[0026] Drawing 3 shows one example of the antenna configuration which carried out termination without going around. the RF antenna 10 currently illustrated -- a cross section -- the inside of the rectangular vacuum housing 1 -- a line -- it is the example of an antenna with the frame of the shape of a rectangle which two antennas which made the character of KO go half round a conductor along with a wall surface were made to counter, carried out parallel connection, and constituted them. When the vacuum housing 1 is making the shape of a cylinder, an antenna with the frame of the circle configuration which two patterns of a semicircle were opposed instead of the pattern of the character of KO, and carried out parallel connection can be used. In addition, it is also possible to carry out parallel connection of the antenna which divided the rectangle or the round shape into three or more patterns if needed, and to use the antenna in which the whole has the frame of the shape of a rectangle and a circle configuration.
[0027] Such a RF antenna 10 that does not go around can reduce sharply the inductance which an antenna has compared with the antenna of the configuration which goes [coil / the conventional loop formation,] around. Consequently, increase of the high-frequency voltage accompanying high-frequency power increase can be controlled.
[0028] A blocking capacitor 7 is inserted between the earth side terminal of the high frequency antenna 10, and touch-down, and high-frequency power is supplied to a drive side edge child through the adjustment machine 11. Drawing 4 (a) and (b) show the equal circuit of the touch-down mold antenna by which direct continuation was carried out to touch-down potential, and the suspension mold antenna connected to touch-down potential through the capacitor. L is the inductance of an antenna, and rc here. The internal resistance of an antenna, C0, C1, and C2 A matching capacitor and Cb A blocking capacitor and omega are the angular frequency of the high frequency current.
[0029] The high-frequency voltage which is generated between high potential side electrical-potential-difference |VH | of a RF antenna and low voltage side electrical-potential-difference |VL | in the case of which [of drawing 4 (a) and (b)] is the inductance L of antenna current Irf and an antenna, and the internal resistance rc of an antenna. It uses and is given by the formula shown in the following several 1.
[0030]
[Equation 1]

$$|V_H - V_L| = |j\omega L + r_c|\, I_{rf} \simeq \omega L I_{rf} \qquad (2)$$

[0031] It sets at the metal antenna generally used here again, and is internal resistance rc. It is small to extent which can be disregarded. Therefore, as shown in drawing 4 (b), it is a blocking capacitor Cb to the termination of an antenna. Potential |VL | of the antenna both ends in the case of the connected suspension mold antenna and |VH | can be expressed with a degree type, respectively.
[0032]
| VL |=(1-/omegaCb) Irf (3)
| VH |=|1-/jomegaCb + jomegaL|Irf (4)
When resonance conditions are satisfied in drawing 4 (a) and (b), it is L and C0. It is set to 1-/omega2 = [C0 C1/(C0+C1)] L=C1 L.
[0033] Moreover, generally, since it is about 50-ohm low impedance, the input impedance in the adjustment machine 11 is C0 >>C1. It fills. Furthermore, at the time of adjustment with an antenna, it is C [1/C1 =1 /] 2+1/Cb. It is satisfied. Consequently, the voltage ratio of the antenna both ends in the suspension mold antenna of drawing 4 (b) can be expressed like a degree type.

[0034]
|VH /VL |=Cb /C2 (5)
Since a low voltage side is fixed to touch-down potential (VL =0V), the amplitude of the high-frequency voltage by the side of the high potential in the case of the touch-down mold antenna which is carrying out direct continuation of the termination of the antenna shown in drawing 4 (a) to touch-down potential serves as omegaLrf.
[0035] On the other hand, the electrical potential difference of the antenna both ends of the suspension mold antenna of drawing 4 (b) becomes smaller than a formula (2) and (5) to omegaLIrf. And termination capacity fulfills an equilibrium condition and it is Cb. C2 When a ratio is set to 1, minimum value VH =VL =omegaLIrf/2 are obtained.
[0036] here, when the simple case where leakage of the high frequency current to the plasma can be disregarded is assumed, it is shown in drawing 5 (a) and (b) -- as -- an antenna -- the high-frequency voltage distributed along with a conductor -- VL from -- VH up to -- it changes in the shape of a straight line. in this case, with the suspension mold antenna which connected the capacitor (Cb) to the antenna termination shown in drawing 5 (b) Each impedance of the blocking capacitor (Cb) inserted between the matching capacitor (C2) in the antenna (L) itself and an adjustment machine and touch-down potential is L= 2/omegaCb =2-/omegaC2 of omega. When satisfied, Electrical potential difference VH by the side of antenna height potential The amplitude serves as half [of the amplitude (omegaLIrf) in the case of the touch-down mold antenna which connected to direct touch-down potential the antenna shown in drawing 5 (a)].
[0037] and the line which does not go around as shown previously -- the amplitude of the high-frequency voltage concerning an antenna can be greatly reduced by combining supplying the high frequency current to the antenna of a conductor, and inserting a capacitor in the termination of an antenna and taking adjustment of an impedance. the shape of for example, a ring as shown in drawing 9 which is one example of the antenna by this invention which does not go around -- in the case of the antenna (double half loop antenna) of a conductor, an inductance is set to one half compared with the case of the antenna of one turn which the conventional method goes around with the diameter of said like mentioned later. For this reason, compared with the conventional method which connects that earth side electrode to touch-down potential directly using the antenna of 1 turn which goes around, the airraid amplitude of high-frequency voltage serves as those abbreviation 1/4. This shows that the high-frequency power of 16 times [no less than] as many high power as this can be supplied compared with the conventional method, when an electrical potential difference comparable as the conventional method is allowed as voltage to ground amplitude generated at an antenna.
[0038]
[Embodiment of the Invention] One example of this invention equipment shown in drawing 1 is explained. this equipment -- the interior of the cylindrical vacuum housing 1 with a diameter [of 400mm], and a height of 200mm -- an antenna -- it fixes to two introductory terminals 8 and 9 prepared in the container side attachment wall, and the RF antenna 14 which consists of a ring electrode with a diameter of 360mm shown in drawing 9 as a conductor 5 is installed. And RF generator shown in one introductory terminal 8 of a container side attachment wall at drawing 9 (frequency: 13.56MHz) 12 is connected through the adjustment machine 11. And all the front faces of this ring electrode are covered with the insulator tube 6 of high grade alumina ceramics (99.6at%) with a thickness of 2mm. Let it be requirements to have the thermal resistance which does not produce a problem even if what it has an impedance larger (for example, single or more figures) enough than the equivalent impedance of a sheath for (Zinsulator >>Zsheath) is required and is further put to the plasma directly in the quality of the material of an insulator, and selection of thickness, as shown also in a formula (1), chemical stability, a mechanical strength, electric insulation, etc. For this reason, thickness should just be about 2-4mm with the quality of the material of the ceramic dielectric group which can fill high resistance, such as high purity alumina, a quartz, and a zirconia, high insulation, and a low dielectric constant to coincidence, for example. Moreover, the capacitor (electrostatic capacity: 400pF) is connected to the introductory terminal 9 of another side, and it is grounded through this capacitor. As shown in drawing 9 , an introductory terminal is arranged so that it may face each other on a diameter line to a ring-like electrode, and has structure (double half loop antenna) which supplies high-frequency power from two nodes on the diameter line of a ring-like electrode. By the supply system of such power, the inductance of an antenna is reduced by half compared with the case of the antenna of 1 turn which has the circumference configuration of the conventional method with the

diameter of said. As a result of measuring the inductance of the ring electrode (full loop formation) used for this example, they were about 1200 nH(s). And as a result of measuring an inductance similarly in double half loop structure, 600nH was obtained, and the inductance was reduced by half.
[0039] Moreover, the langmuir probe for plasma measurement was introduced using the introductory flange of a container side attachment wall, and the plasma state was measured with this probe.
[0040] First, after exhausting the inside of a vacuum housing up to 1x10 to 4 Pa with a vacuum pump, from the gas inlet which is not illustrated, argon gas (Ar) was introduced to 1.1 Pa, high-frequency power was switched on to 120W-2400W, and the plasma was generated in the vacuum housing. At this time, the plasma consistency of a vacuum housing core (antenna installation side - 65mm) was measured with the langmuir probe.
[0041] Moreover, in order to examine the effectiveness of the capacitor inserted in the earth side of an antenna, about the case (touch-down mold antenna) where it connects with direct touch-down potential, it experimented and the case (suspension mold antenna) where a capacitor was inserted was compared with antenna termination.

[0042] The relation of the RF injection power (Prf) and the plasma consistency (np) in the antenna condition of a suspension mold antenna and each touch-down mold antenna is shown in drawing 6 . it sees in this drawing -- as -- a suspension mold antenna and a touch-down mold antenna -- any -- also setting -- the increment in Prf -- following -- np np increase, and the high density plasma of 5x1011 (cm3) is acquired for a charged-particle consistency by Prf=2.4kW, and according to the difference in an antenna touch-down condition It turns out that there is no difference. Moreover, the plasma consistency obtained by this example shows that the high density plasma of utilization level is acquired easily, even when the diameter of a discharge room by the conventional method was comparable as what is obtained with the plasma generator below 300mmphi, or had become a high value from it, and it diameter[of macrostomia]-izes compared with the plasma generator of the conventional method according to the plasma generating method of this invention.
[0043] Furthermore, change of the high-frequency voltage (Vantenna) in the touch-down mold antenna measured with the oscilloscope to coincidence and each suspension mold antenna is shown in drawing 7 . In the case of a touch-down mold antenna, it is np. In the field beyond Prf500W which becomes more than 1x1011 (cm3), it is dependent on the increment in Prf, and Vantenna. It increases. On the other hand, in the case of the suspension mold antenna which fulfills a high-frequency-voltage equilibrium condition, it is Vantenna not more than the one half in the case of a touch-down mold antenna, or it. A value is shown. And with the touch-down mold antenna, about 1/is stopped by the electrical potential difference of 3 with Vantenna =600V with the suspension mold antenna to Vantenna = abbreviation 1800V at the time of Prf=2.5kw. Inserting in the earth side of an antenna the capacitor which fulfills a high-frequency voltage equilibrium condition from these results enables reduction of the electrical-potential-difference value concerning an antenna, without reducing a plasma consistency, and it makes easy generation of the stable high density plasma by large power injection.
[0044] The same equipment as the example of drawing 1 is used, and it is argon gas (Ar). It introduced to 1.1 Pa, high-frequency power was switched on to 120W-2400W, and the plasma was generated in the vacuum housing. The termination of an antenna was connected to direct touch-down potential at this time. Moreover, in order to examine the effectiveness of insulator covering on the front face of an antenna at this time, it compared with the antenna front face by conducting the same experiment about the case where it does not consider as the case where an insulator is covered.
[0045] Change of the plasma consistency (np) to the RF injection power (Prf) in each antenna condition is shown in drawing 8 . In the case of an antenna condition without insulator covering, depending on the increment in Prf, a plasma consistency (np) increases to Prf=500W. However, when it became more than Prf=500W, abnormality discharge occurred frequently in the everywhere in a vacuum housing (for example, introductory terminal area), and the stable plasma was not able to be acquired. Plasma potential rises rapidly with the increment in a plasma consistency, consequently this is considered that abnormality discharge arose in every place in a vacuum housing.
[0046] On the other hand, it is np, without causing abnormality discharge to the increment in Prf with the antenna covered with the insulator. It increases, and by Prf=2.4kw, the high density plasma of 5x1011 (cm-3) is stabilized, and is acquired. By having covered the antenna front face with the insulator, the electron which flows into an antenna from the plasma is intercepted, and this is considered to originate in as a result the rise of plasma potential having been controlled. Thus, it became clear that the high density plasma stabilized by

covering an antenna front face with an insulator is acquired.
[0047] Drawing 9 shows the example of the antenna which used the ring-like conductor. what 13 are a cylinder-like vacuum housing among drawing, and showed the cross section, and the shape of a ring by which 14 has been arranged in accordance with the wall of a vacuum housing 13 -- it is the RF antenna which consists of a conductor. the shape of a ring -- the diameter line of the arbitration of a conductor -- the 2 The node of a driving side and the node of the earth side are set as the endpoint of **. the RF antenna 14 -- these two nodes -- two symmetrical hemicycles -- a line -- it has the structure which carried out parallel connection of the frame of a conductor. The high frequency current is supplied from RF generator 12 through the adjustment machine 11 at the node of a driving side, and the blocking capacitor 7 is inserted between the node of the earth side, and touch-down.
[0048] Drawing 10 and drawing 11 show the deformation example of the equipment shown in drawing 3 .
[0049] the whole the RF antenna 16 in the example of drawing 10 is indicated to be to drawing 3 -- the inside of the RF antenna 10 of the shape of a rectangular frame -- the shape of two or more straight lines -- although a conductor is arranged in the shape of a fence and it has the same function substantially with the case of the example of drawing 9 -- the high frequency current -- the shape of two or more straight line -- since it can pass in parallel to a conductor, especially a cross section is effective in performing high density plasma production within the rectangular vacuum housing 15.
[0050] Moreover, the example shown in drawing 11 is a multi-mold straight-line-like antenna which has arranged two or more straight-line-like antennas 18a-18f along with the internal surface of a vacuum housing 17 a lengthwise direction, a longitudinal direction, or in the shape of two-dimensional. Parallel connection of each straight-line-like antennas 18a-18f is carried out on the outside of a vacuum housing 17, and a blocking capacitor 7 is connected with the adjustment machine 11. Although the example of drawing 11 has the same function substantially with the case of the example of drawing 9 R> 9 if the point which is a multi-mold straight-line-like antenna is removed, it is effective in performing high density plasma production within the vacuum housing of a major axis especially with the diameter of macrostomia. In addition, it is also possible to change each straight-line-like antennas 18a-18f into the antenna of the typeface of KO or a radii form if needed.

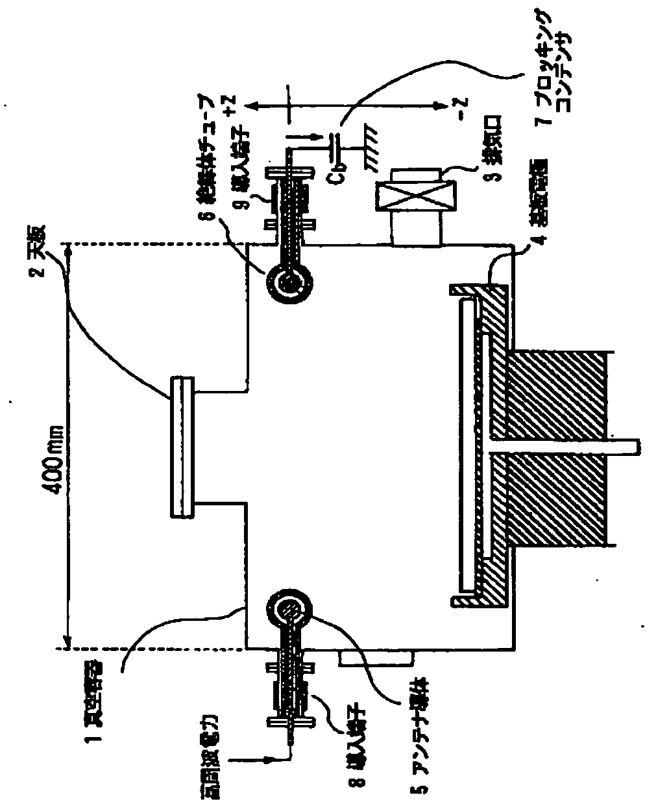
[0051] Moreover, in examples, such as drawing 1 , drawing 3 , drawing 9 , drawing 10 , and drawing 11 , the uniformity of a plasma consistency can be further raised by adding suitable field generating means, such as attaching the permanent magnet of a multi-cusp mold in accordance with the outer wall of a vacuum housing.
[0052]
[Effect of the Invention] In this invention, since the antenna for plasma production itself is installed in a vacuum housing, it is not restricted to the configuration, aperture, and die length of a discharge room. moreover, an antenna -- by covering all the front faces of a conductor with an insulator, it becomes possible to be stabilized and to generate the high density plasma of the diameter of macrostomia, and the large volume.
[0053] In order to control the increment in the inductance accompanying enlargement of an antenna by this invention furthermore, Since it is high-density and the plasma with low plasma potential is generated, when the linear conductor which does not go around is used for an antenna and electric capacity, in addition, inserts and adjusts immobilization or an adjustable capacitor between the termination of an antenna, and touch-down, Since the high-frequency power of large power can be supplied without generating abnormality discharge while making plasma treatment with few damages realizable, it is easy to attain densification of the plasma.

[Translation done.]

DRAWINGS

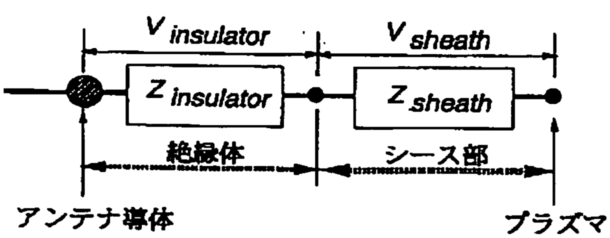
[Drawing 1]

本発明によるプラズマ発生装置の基本構成



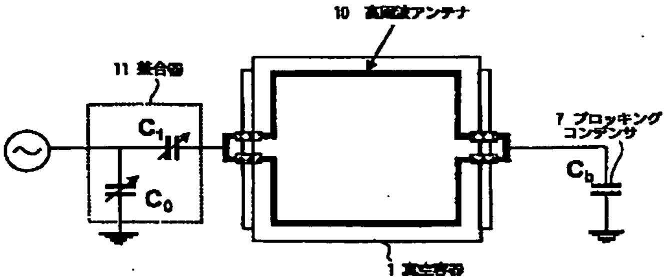
[Drawing 2]

アンテナ導体を絶縁体で被覆した場合の等価回路

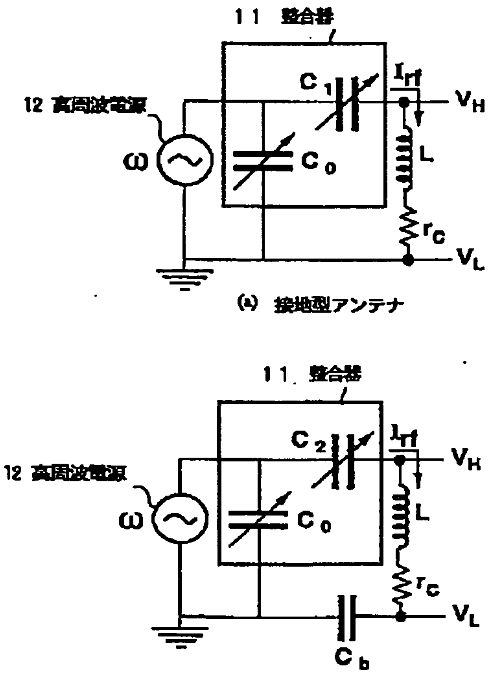


[Drawing 3]

周回しないアンテナ形状の例



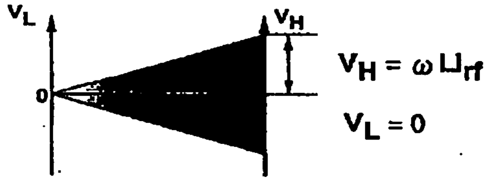
[Drawing 4]
接地型アンテナと浮遊型アンテナの等価回路



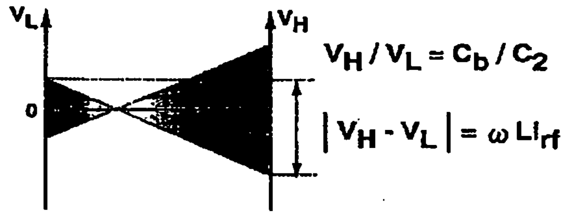
(b) 浮遊型アンテナ

[Drawing 5]

接地型アンテナと浮遊型アンテナの電圧分布

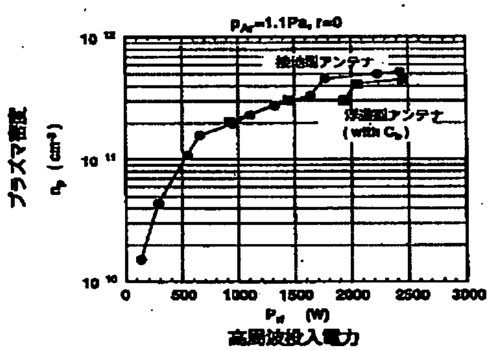


(a) 浮遊型アンテナ

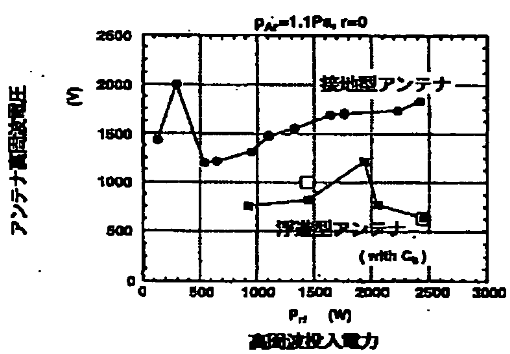


(b) 接地型アンテナ

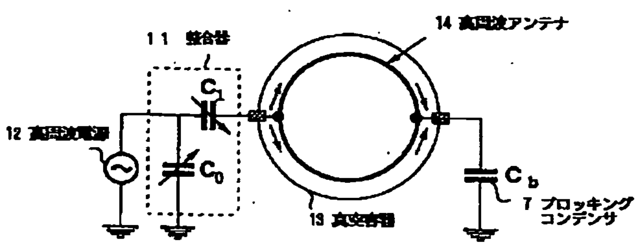
[Drawing 6]
接地型アンテナと浮遊型アンテナにおける
高周波投入電力とプラズマ密度の関係



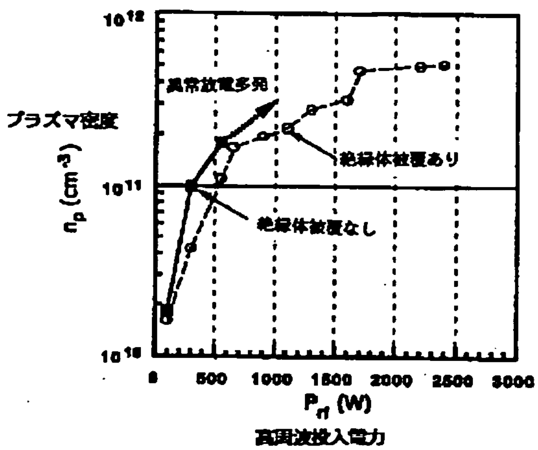
[Drawing 7]
接地型アンテナと浮遊型アンテナにおける
高周波電圧の変化



[Drawing 9]
リング状の導体を用いたアンテナの実施例

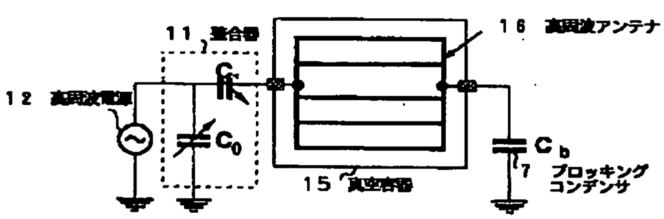


[Drawing 8]
アンテナ表面の絶縁体被覆の効果

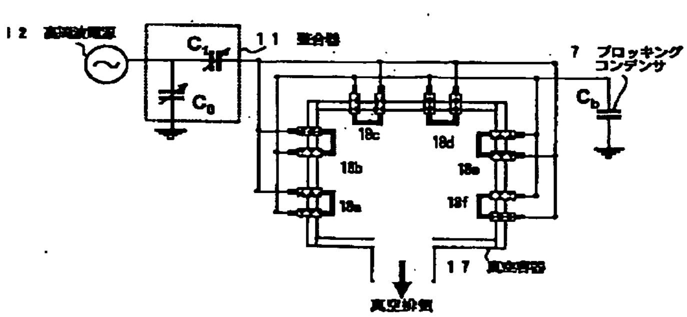


[Drawing 10]

柵状の導体を用いたアンテナの実施例

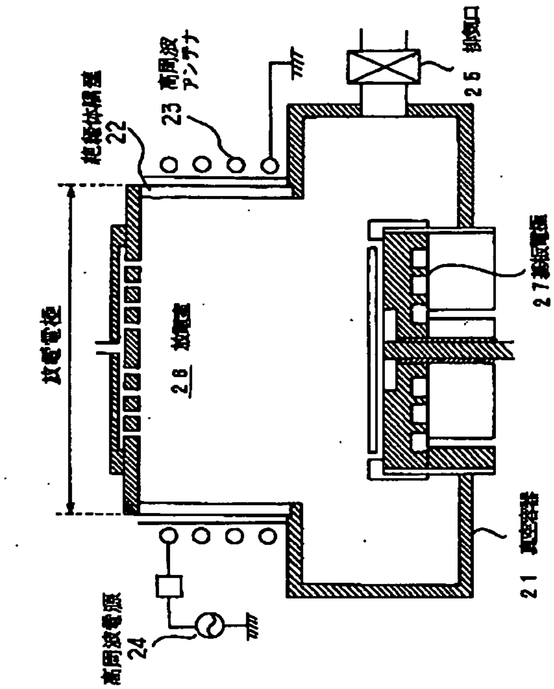


[Drawing 11]
複数の直線状導体を用いたアンテナの実施例



[Drawing 12]

従来のＩＣＰを用いたプラズマ処理装置の１例



[Translation done.]

CORRECTION OR AMENDMENT

[Kind of official gazette] Printing of amendment by the convention of 2 of Article 17 of Patent Law
[Section partition] The 1st partition of the 7th section
[Publication date] October 25, Heisei 14 (2002. 10.25)

[Publication No.] JP,2001-35697,A (P2001-35697A)
[Date of Publication] February 9, Heisei 13 (2001. 2.9)
[Annual volume number] Open patent official report 13-357
[Application number] Japanese Patent Application No. 11-212238
[The 7th edition of International Patent Classification]

```
H05H   1/46
H01L  21/3065
```

[FI]

```
H05H   1/46        L
H01L  21/302       B
```

[Procedure revision]
[Filing Date] July 24, Heisei 14 (2002. 7.24)
[Procedure amendment 1]
[Document to be Amended] Specification
[Item(s) to be Amended] Claim
[Method of Amendment] Modification
[Proposed Amendment]
[Claim(s)]
[Claim 1] It is the plasma generator which installs the antenna which impresses high-frequency power and is made to generate induction field in the plasma generator of the inductive-coupling method by high frequency discharge in a vacuum housing, and is characterized by said antenna consisting of ring-like multipole antennas.
[Claim 2] It is the plasma generator which installs the antenna which impresses high-frequency power and is made to generate induction field in the plasma generator of the inductive-coupling method by high frequency discharge in a vacuum housing, and is characterized by said antenna consisting of linear conductors which carry out termination without going around.
[Claim 3] It is the plasma generator characterized by an antenna consisting of linear conductors of the typeface of at least one or more KO, or a radii form in the plasma generator shown in claim 2.
[Claim 4] The plasma generator characterized by arranging the linear conductor which forms the frame of the typeface of two KO which constitutes an antenna, or a hemicycle in the plasma generator shown in claim 3 in accordance with the wall of a vacuum housing.
[Claim 5] at least one or more shape of a straight line by which said antenna is arranged in accordance with the wall of said vacuum housing which installs the antenna which impresses high-frequency power and is made to generate induction field in the plasma generator of the inductive-coupling method by high frequency discharge in a vacuum housing -- it constitutes from a conductor -- having -- these shape of one or more straight line -- the

plasma generator characterized by supplying the high frequency current to juxtaposition to each of a conductor.
[Claim 6] in the plasma generator of the inductive-coupling method by high frequency discharge, the antenna which impresses high-frequency power and is made to generate induction field is installed in a vacuum housing, and said antenna consists of ring-like conductors -- having -- the shape of this ring -- one with a conductor -- this -- for other one point which counters one point on a diameter line -- the shape of a ring -- the plasma generator characterized by supplying the high frequency current to a conductor.
[Claim 7] The plasma generator characterized by forming the field generating means which makes a plasma consistency uniform in the outside of said vacuum housing in the plasma generator shown in either claim 1, claim 2, claim 5 or claim 6.
[Claim 8] The plasma generator characterized by electric capacity inserting immobilization or an adjustable capacitor between the node of the earth side of said antenna, and touch-down in the plasma generator shown in either claim 1, claim 2, claim 5 or claim 6.
[Claim 9] The plasma generator characterized by using either argon gas, hydrogen gas or nitrogen gas as a controlled atmosphere introduced in said vacuum housing in the plasma generator shown in either claim 1, claim 2, claim 5 or claim 6.
[Procedure amendment 2]
[Document to be Amended] Specification
[Item(s) to be Amended] 0010
[Method of Amendment] Modification
[Proposed Amendment]
[0010] For this reason, in this invention, the antenna itself is installed in the location of the arbitration in a vacuum housing, and it is characterized by constituting said antenna with a ring-like multipole antenna so that it may describe at claim 1. It becomes possible to generate the high density plasma of the diameter of macrostomia, without being restricted to the configuration, aperture, and die length of a discharge room by this.
[Procedure amendment 3]
[Document to be Amended] Specification
[Item(s) to be Amended] 0011
[Method of Amendment] Modification
[Proposed Amendment]
[0011] Furthermore, by this invention, in order to control the increment in the inductance accompanying enlargement of an antenna so that it may describe at claim 2, the antenna itself is installed in the location of the arbitration in a vacuum housing, and said antenna is characterized by consisting of linear conductors which carry out termination without going around.
[Procedure amendment 4]
[Document to be Amended] Specification
[Item(s) to be Amended] 0012
[Method of Amendment] Modification
[Proposed Amendment]
[0012] Furthermore, by this invention, it is characterized by constituting said antenna from a linear conductor of the typeface of at least one or more KO, or a radii form so that it may describe at claim 3.
[Procedure amendment 5]
[Document to be Amended] Specification
[Item(s) to be Amended] 0013
[Method of Amendment] Modification
[Proposed Amendment]
[0013] Furthermore, by this invention, it is characterized by arranging the linear conductor which forms the frame of the typeface of two KO which constitutes said antenna, or a hemicycle in accordance with the wall of a vacuum housing so that it may describe at claim 4.
[Procedure amendment 6]
[Document to be Amended] Specification
[Item(s) to be Amended] 0014
[Method of Amendment] Modification
[Proposed Amendment]

[0014] at least one or more shape of a straight line which installed the antenna itself in the location of the arbitration in a vacuum housing, and has furthermore arranged said antenna in accordance with the wall of a vacuum housing by this invention so that it may describe at claim 5 -- a conductor -- constituting -- these shape of one or more straight line -- it is characterized also by supplying the high frequency current to juxtaposition to each of a conductor.
[Procedure amendment 7]
[Document to be Amended] Specification
[Item(s) to be Amended] 0015
[Method of Amendment] Modification
[Proposed Amendment]
[0015] furthermore, this invention describes to claim 6 -- as -- the antenna itself -- the location of the arbitration in a vacuum housing -- installing -- said antenna -- a ring-like conductor -- constituting -- the shape of this ring -- one with a conductor -- this -- for other one point which counters one point on a diameter line -- the shape of a ring -- it is characterized also by supplying the high frequency current to a conductor.
[Procedure amendment 8]
[Document to be Amended] Specification
[Item(s) to be Amended] 0016
[Method of Amendment] Modification
[Proposed Amendment]
[0016] Furthermore, by this invention, it is characterized by attaching a field generating means like the permanent magnet of a multi-cusp mold in accordance with the outer wall of a vacuum housing so that it may describe at claim 7, and the consistency of the plasma in a vacuum housing may become uniform.
[Procedure amendment 9]
[Document to be Amended] Specification
[Item(s) to be Amended] 0017
[Method of Amendment] Modification
[Proposed Amendment]
[0017] Furthermore, by this invention, in order to control the high-frequency-voltage increase by large power injection so that it may describe at claim 8, when electric capacity inserts immobilization or an adjustable capacitor between the termination of an antenna, and touch-down, it is characterized by reducing by half the airraid high-frequency voltage generated at an antenna.
[Procedure amendment 10]
[Document to be Amended] Specification
[Item(s) to be Amended] 0018
[Method of Amendment] Modification
[Proposed Amendment]
[0018] Furthermore, by this invention, it is characterized by using either argon gas, hydrogen gas or nitrogen gas as a controlled atmosphere introduced in a vacuum housing so that it may describe at claim 9.
[Procedure amendment 11]
[Document to be Amended] Specification
[Item(s) to be Amended] 0019
[Method of Amendment] Deletion

[Translation done.]

(19) 日本国特許庁（ＪＰ）

(12) 公開特許公報（Ａ）

(11) 特許出願公開番号
特開2001－35697
（Ｐ２００１－３５６９７Ａ）

(43) 公開日　平成13年２月９日(2001.2.9)

(51) Int.Cl.⁷	識別記号	ＦＩ	テーマコード（参考）
H05H 1/46		H05H 1/46	L 5F004
H01L 21/3065		H01L 21/302	B

審査請求　未請求　請求項の数10　ＯＬ　（全９頁）

(21) 出願番号　特願平11－212238

(22) 出願日　平成11年７月27日(1999.7.27)

(71) 出願人　396020800
科学技術振興事業団
埼玉県川口市本町４丁目１番８号

(72) 発明者　三宅　正司
大阪府吹田市青葉丘南８番　Ｐ－505

(72) 発明者　庄司　多津男
愛知県名古屋市瑞穂区松月町２－45　メゾン松月　202

(72) 発明者　節原　裕一
大阪府箕面市小野原東３－11－15－245

(74) 代理人　100087147
弁理士　長谷川　文廣

最終頁に続く

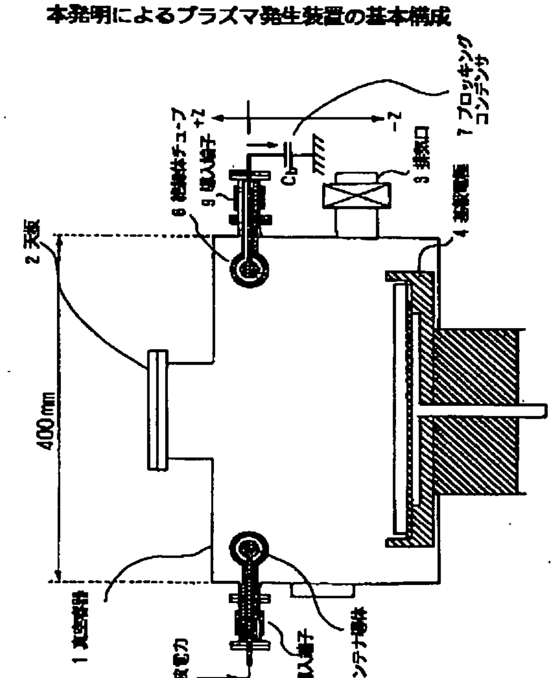
(54)【発明の名称】プラズマ発生装置

(57)【要約】

【課題】大面積基板のエッチングや薄膜形成等の表面処理を行うのに有用なプラズマ発生装置に関わり、真空容器に絶縁体の隔壁部あるいは天板を設けてその外側に高周波アンテナを設置する従来の誘導結合型プラズマ発生装置では、放電室の径が大きくなるにつれ絶縁体の厚みを大幅に増大させなければならず、高周波電力の利用効率が低下するという問題があった。

【解決手段】プラズマ発生装置の真空容器１の内部にアンテナ導体５全体を入れ、絶縁体の隔壁や天板を用いる必要をなくして、アンテナから放射される誘導電界の全てを有効利用できるようにした。またアンテナのインダクタンスを小さくしたり、アンテナ導体を絶縁体で被覆したりして異常放電の発生を抑制し、高密度プラズマの安定化を図っている。

本発明によるプラズマ発生装置の基本構成



【特許請求の範囲】

【請求項１】　高周波放電による誘導結合方式のプラズマ発生装置において、高周波電力を印加して誘導電界を発生させるアンテナを真空容器内に設置したことを特徴とするプラズマ発生装置。

【請求項２】　請求項１に示されたプラズマ発生装置において、アンテナの全表面が真空に曝されていることを特徴とするプラズマ発生装置。

【請求項３】　請求項１に示されたプラズマ発生装置において、アンテナの全表面が絶縁体で被覆されていることを特徴とするプラズマ発生装置。

【請求項４】　請求項１に示されたプラズマ発生装置において、アンテナは周回しないで終端する線状の導体で構成されていることを特徴とするプラズマ発生装置。

【請求項５】　請求項１ないし請求項４に示されたプラズマ発生装置において、アンテナは少なくとも１つ以上のコの字形または円弧形の線状の導体で構成されることを特徴とするプラズマ発生装置。

【請求項６】　請求項５に示されたプラズマ発生装置において、アンテナを構成する２つのコの字形または半円形の枠を形成する線状の導体が真空容器の内壁に沿って配置されていることを特徴とするプラズマ発生装置。

【請求項７】　請求項１ないし請求項４に示されたプラズマ発生装置において、アンテナは真空容器の内壁に沿って配置されている少なくとも１つ以上の直線状導体で構成され、それら１つ以上の直線状導体の各々へ高周波電流を並列に供給することを特徴とするプラズマ発生装置。

【請求項８】　請求項１ないし請求項４に示されたプラズマ発生装置において、アンテナはリング状の導体で構成され、該リング状導体のある一点と、該一点に直径線上で対向する他の一点との間でリング状導体に高周波電流を供給することを特徴とするプラズマ発生装置。

【請求項９】　請求項１ないし請求項４に示されたプラズマ発生装置において、真空容器の外側に、プラズマ密度を一様にする磁界発生手段を設けたことを特徴とするプラズマ発生装置。

【請求項１０】　請求項１ないし請求項４に示されたプラズマ発生装置において、アンテナの接地側の接続点と接地との間に、電気容量が固定または可変のコンデンサを挿入したことを特徴とするプラズマ発生装置。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、アンテナに高周波電流を供給して高周波電界を発生させ、その電界によりプラズマを発生して、基板面にエッチングや薄膜形成等の表面処理を行うプラズマ処理装置に有用なプラズマ発生装置に関わり、特に液晶用ガラス基板等の大面積基板を処理するのに適するものである。

【０００２】

【従来の技術】半導体デバイスや液晶ディスプレイの製造工程で使用されるドライエッチング装置やアッシング装置、プラズマＣＶＤ装置等のプラズマを用いた処理装置の分野においては、近年の処理基板の大型化に伴い、処理装置のプラズマ源も大口径化が要求されている。また、一方では、エッチングレートや成膜速度、スループットを確保するため、高真空下でのプラズマの高密度化が要求されている。

【０００３】このうち、プラズマの高密度化に関しては、プラズマの励起効率を促進するために、高周波を用いて誘導結合プラズマ（Inductively Coupled Plasma、以下ＩＣＰと略称）を発生させる方法が採用されている。ＩＣＰは主としてアンテナ励起用コイルに高周波電流を流し、これによって真空中に誘導電磁界を発生させ、プラズマを生成するものであり、高真空下において高密度プラズマを均一に生成することができる。

【０００４】従来のＩＣＰを用いたプラズマ処理装置の１例を図１２に示す。図１２において、２１は基板のエッチング処理等を行なう真空容器（プロセスチャンバー）、２２は真空容器の一部に設けられた石英等の絶縁体隔壁、２３は絶縁体隔壁２２の大気側の壁面に沿ってループ状あるいはスパイラル状に設けられた１ターン以上の巻数を有する周回形状の高周波アンテナ、２４は高周波アンテナに高周波電力を供給する高周波電源、２５は排気口、２６は放電プラズマが生成される放電室、２７は基板電極である。

【０００５】しかし、図１２の従来方式では、放電室２６の径を４００ｍｍφ以上に大口径化しようとすれば、大気圧下にある外気と高真空下にある放電室内との圧力差に抗するのに必要となる機械的強度を得るために、絶縁体隔壁２２の肉厚を１０～３０ｍｍもの厚みにしなくてはならず、このため高周波アンテナ２３から放射される誘導電界強度は、アンテナから遠くなるに従って指数関数的に減少して放電効率が悪くなり、アンテナ２３のインダクタンスが大きくなってアンテナに発生する高周波電圧が高くなってしまうこと等の問題があった。

【０００６】一方、このように放電室の側面を周回させるようにアンテナを設ける代わりに、真空容器の放電室上面を絶縁体の天板にして、その外側にアンテナを設置する方式もあった。しかしこの方式では、現状での放電室径が３００ｍｍφのものの天板の絶縁体の厚みが２０ｍｍ程度であるのに対し、放電室径を４００ｍｍφ以上に大口径化しようとした場合には、機械的強度を確保するために３０～５０ｍｍもの厚みが必要となるという問題があった。

【０００７】

【発明が解決しようとする課題】真空容器の絶縁体隔壁あるいは天板の大気側の壁面に高周波アンテナを設置する従来の誘導結合型プラズマ発生装置では、放電室の径が大きくなるにつれ絶縁体の厚みを大幅に増大させなけ

ればならず、またアンテナから放射される誘導電界の内、真空容器の絶縁体隔壁あるいは天板に接する面の側に放射される誘導電界成分のみしか放電維持に利用されないため、投入される高周波電力の利用効率が悪いという問題があった。

【０００８】

【課題を解決するための手段】上記の問題点を解決するために、本発明によるプラズマ発生装置においては、アンテナ自体を真空容器内部の任意の場所に設置し、つまり内部アンテナにしてアンテナの全表面が真空内にあるようにし、アンテナから放射される誘導電界の全てを有効利用できるようにするとともに絶縁体の隔壁や天板を用いる必要をなくしている。また同時に本発明では、内部アンテナの場合、アンテナに大きな電圧が印加されると異常放電を生じやすくなることから、アンテナのインダクタンスを極力小さくし、少なくともアンテナが１ターン以上周回しない構造としている。以下に、本発明の原理について詳述する。

【０００９】アンテナを真空チャンバー内に導入した場合、アンテナ自体がプラズマに曝される為、アンテナに印加される電圧に依存してイオンや電子がアンテナに流入する。この時プラズマ中のイオンと電子の高周波電磁界に対する移動速度が大きく異なることから、時間平均では実効的にプラズマ中の電子がアンテナへ過剰に流入してプラズマ電位が上昇する。その結果、投入高周波電力の増加によるプラズマの高密度化に伴いアンテナ導体との静電結合によるプラズマ電位の上昇が顕著となり、真空容器内に異常放電を引き起こす。この様に内部アンテナ型のＩＣＰプラズマでは安定した高密度プラズマが得にくいという問題がある。また、静電結合の増加は、アンテナからシースを介してプラズマに印加される高周波電圧の振幅を大きくする。高周波電圧の振幅の増大は、プラズマの乱れ（プラズマ電位の高周波変動の増大）を誘発する。その結果、エッチングや薄膜形成時におけるプラズマの揺らぎが大きくなり（例えばイオン入射エネルギーの増大）、プラズマダメージの影響が懸念される。よって、内部アンテナ型のＩＣＰプラズマ生成においては、印加する高周波電圧の低動作電圧化が重要であり、そのためには、アンテナのインダクタンス低減および静電結合の抑制が必要である。

【００１０】このため本発明では、請求項１に記するようにアンテナ自体を真空容器内の任意の場所に設置することを特徴とする。これにより放電室の形状や口径および長さに制限されることなく、大口径の高密度プラズマを生成することが可能となる。

【００１１】また本発明では、請求項２に記するように、当該アンテナの全表面が真空に曝されていることをも特徴とする。

【００１２】さらに本発明では、請求項３に記するように、内部アンテナ化に伴う静電結合の増加を抑制するため、アンテナ導体の表面を全て絶縁体で被覆することをも特徴とする。

【００１３】さらに本発明では、請求項４に記するように、アンテナの大型化に伴うインダクタンスの増加を抑制するため、アンテナは周回しないで終端する線状の導体で構成することを特徴とする。

【００１４】さらに本発明では、請求項５に記するように、アンテナを、少なくとも１つ以上のコの字形または円弧形の線状の導体で構成することにより、インダクタンスの減少を図ることをも特徴とする。

【００１５】さらに本発明では、請求項６に記するように、アンテナは２つのコの字形または半円形の枠を形成する線状の導体を真空容器の内壁に沿って配置する構造をとることをも特徴とする。

【００１６】さらに本発明では、請求項７に記するように、アンテナは真空容器の内壁に沿って配置した少なくとも１つ以上の直線状導体で構成し、それら１つ以上の直線状導体の各々へ高周波電流を並列に供給することをも特徴とする。

【００１７】さらに本発明では、請求項８に記するように、アンテナをリング状の導体で構成し、該リング状導体のある一点と、該一点に直径線上で対向する他の一点との間でリング状導体に高周波電流を供給することをも特徴とする。

【００１８】さらに本発明では、請求項９に記するように、真空容器内のプラズマの密度が一様になるよう、真空容器の外壁に沿ってマルチカスプ型の永久磁石を取り付けたことを特徴とする。

【００１９】さらに本発明では、請求項10に記するように、大電力投入による高周波電圧増大を抑制するため、アンテナの終端と接地との間に電気容量が固定または可変のコンデンサを挿入することにより、アンテナに発生する対地高周波電圧を半減することを特徴とする。

【００２０】本発明によるプラズマ発生装置の基本構成を、図１により説明する。なお、図１には、便宜上、本発明の１実施例装置の構成が示されているが、本発明はこれに限定されるものではない。

【００２１】図１において、１は真空容器（プロセスチェンバー）、２は天板、３は排気口、４は基板電極、５は本発明によるアンテナ導体、６はアンテナ導体５の全表面を被覆する絶縁体チューブ、７はアンテナ導体５を接地から浮遊（フローティング）させる容量が固定あるいは可変のブロッキングコンデンサ、８、９はアンテナ導体５を支持するとともにアンテナ導体５に高周波電力を供給する導入端子である。

【００２２】アンテナ導体５は、図では断面のみが示されているが、真空容器１の内壁面に沿って配置された1つ以上のコの字形あるいは円弧形等の種々の形状の線状導体で構成される。それらの線状導体は、いずれも真空容器１の内壁面を周回しない長さ、つまり内壁面を一周

しないで終端する長さにつくられる。具体的には、例えば図３、図９、図１０、図１１に示されているようなアンテナのパターンなどが適用できる。

【００２３】プラズマ励起用のアンテナ全体が真空容器１内に収容されているため、真空容器の一部を厚い絶縁体材料で形成する必要がなく、装置の大口径化が容易であり、アンテナの形状変更も任意かつ容易に行うことができる。

【００２４】図示のように、真空容器１内でアンテナ導体５の全表面を絶縁体チューブ６で覆った場合、図２の等価回路に示すように、プラズマのシース領域に印加される電圧（V_{sheath}）は、アンテナに発生する電圧（$V_{antenna}$）と絶縁体における電位降下分（$V_{insulator}$）を用いて次式のように表すことができる。

$$V_{sheath}=V_{antenna}-V_{insulator}=V_{antenna}\ Z_{sheath}/(Z_{insulator}+Z_{sheath}) \qquad (1)$$

ここで$Z_{insulator}$及びZ_{sheath}は絶縁体及びシース領域のインピーダンスを示す。これらインピーダンスは主に抵抗成分と静電容量成分で構成されている。高周波電力を増大させプラズマの密度が増加した際、プラズマ中の等価抵抗（抵抗成分）の減少とシースの厚みの低下による静電容量の増加（注：シースの静電容量はシースの厚さに逆比例する。）のためにZ_{sheath}は減少する。（注：インピーダンスの静電容量成分は静電容量の逆数比例するため、シースの静電容量増加はインピーダンスの減少に寄与する。）これに対し$Z_{insulator}$はプラズマ状態に関わらず一定であることにより、プラズマ密度が高くなるほどV_{sheath}の値は小さくなる。この様にアンテナ表面を絶縁体で被覆することにより、アンテナへの電子流入が遮断され、アンテナとプラズマとの静電結合成分が抑制される。その結果、プラズマの高密度化に伴うプラズマ電位の急増が抑制され、異常放電を起こすことなく安定した高密度プラズマ生成が可能になる。また、シース電位が小さくなることにより、プラズマによる真空容器内壁やアンテナへのスパッタリングが抑制され、基材表面や薄膜中への不純物混入を低減できる。

【００２５】絶縁体の材質ならびに厚さの選択にあたっては、シースの等価インピーダンスよりも十分（例えば一桁以上）大きいインピーダンスを有する（$Z_{insulator}>>Z_{sheath}$）ことが必要であり、さらにはプラズマに直接曝されても問題を生じない耐熱性、化学的安定性、機械的強度、電気絶縁性等を有することを要件とする。このため、例えば高純度アルミナ、石英、ジルコニア等の高抵抗、高絶縁性、低誘電率を同時に満たすことが可能なセラミックス誘電体群の材質で、厚みは２〜４ｍｍ程度であればよい。

【００２６】図３は、周回しないで終端させたアンテナ形状の１例を示す。図示されている高周波アンテナ１０は、断面が矩形の真空容器１内で、線状導体を壁面に沿ってコの字に半周させたアンテナを２つ対向させ、並列接続して構成した矩形状の枠を持つアンテナの例である。真空容器１が円筒状をなしている場合には、コの字のパターンの代わりに半円のパターンを２つ向き合わせて並列接続した円形状の枠を持つアンテナを用いることができる。なお、必要に応じて矩形あるいは円形を３つ以上のパターンに分割したアンテナを並列接続して、全体が矩形状あるいは円形状の枠を持つアンテナを用いることも可能である。

【００２７】このような周回しない高周波アンテナ１０は、従来のループやコイルなどの周回する形状のアンテナに比べ、アンテナの持つインダクタンスを大幅に低減できる。その結果、高周波電力増大に伴う高周波電圧の増大を抑制することが出来る。

【００２８】高周波アンテナ１０の接地側端子と接地との間には、ブロッキングコンデンサ７が挿入され、駆動側端子へは、整合器１１を介して高周波電力が供給される。図４（ａ）、（ｂ）は、接地電位に直接接続された接地型アンテナと、コンデンサを介して接地電位に接続された浮遊型アンテナの等価回路を示す。ここでＬはアンテナのインダクタンス、r_cはアンテナの内部抵抗、C_0、C_1、C_2はマッチングコンデンサ、C_bはブロッキングコンデンサ、ωは高周波電流の角周波数である。

【００２９】図４（ａ）、（ｂ）の何れの場合においても、高周波アンテナの高電位側電圧$|V_H|$と低電位側電圧$|V_L|$との間に発生する高周波電圧は、アンテナ電流I_{rf}、アンテナのインダクタンスＬ、アンテナの内部抵抗r_cを用いて、次の数１に示す式で与えられる。

【００３０】

【数１】

$$|V_H-V_L|=|j\omega L+r_c|I_{rf}\simeq\omega L I_{rf} \qquad (2)$$

【００３１】ここで、また一般に使用される金属製アンテナにおいては、内部抵抗r_cは無視できる程度に小さい。したがって図４（ｂ）に示すように、アンテナの終端にブロッキングコンデンサC_bを接続した浮遊型アンテナの場合のアンテナ両端の電位$|V_L|$、$|V_H|$はそれぞれ次式で表せる。

【００３２】

$$|V_L|=(1/\omega C_b)\ I_{rf} \qquad (3)$$

$$|V_H|=|1/j\omega C_b+j\omega L|\ I_{rf} \qquad (4)$$

図４（ａ）、（ｂ）において共振条件が成立する時、ＬとC₀は$1/\omega^2=[C_0 C_1/(C_0+C_1)]L=C_1 L$となる。

【００３３】また、一般に整合器１１における入力インピーダンスは５０オーム程度の低インピーダンスであるため、$C_0 >> C_1$ を満たす。さらに、アンテナとの整合時には$1/C_1=1/C_2+1/C_b$を満足する。その結果、図４（ｂ）の浮遊型アンテナにおけるアンテナ両端の電圧比は次式のように表せる。

【００３４】

$$|V_H/V_L|=C_b/C_2 \qquad (5)$$

図４（ａ）に示すアンテナの終端を接地電位に直接接続している接地型アンテナの場合における高電位側の高周波電圧の振幅は、低電位側が接地電位（$V_L=0V$）に固定されるのでωL_{rf}となる。

【００３５】これに対し図４（ｂ）の浮遊型アンテナのアンテナ両端の電圧は、式（２）、（５）から$\omega L I_{rf}$より小さくなる。そして終端容量が平衡条件を満たしてC_b とC_2 の比が１となる時、最小値$V_H=V_L=\omega L I_{rf}/2$が得られる。

【００３６】ここで、プラズマへの高周波電流の漏洩が無視できる単純な場合を想定すると、図５（ａ）、（ｂ）に示すように、アンテナ導体に沿って分布する高周波電圧は、V_L からV_H まで直線状に変化する。この場合、図５（ｂ）に示すアンテナ終端にコンデンサ（C_b）を接続した浮遊型アンテナでは、アンテナ自体（Ｌ）と整合器内のマッチングコンデンサ（C_2）及び接地電位の間に挿入したブロッキングコンデンサ（C_b）の各インピーダンスが$\omega L=2/\omega C_b=2/\omega C_2$ を満足するとき、アンテナ高電位側の電圧V_H の振幅は、図５（ａ）に示すアンテナを直接接地電位に接続した接地型アンテナの場合の振幅（$\omega L I_{rf}$）の半分となる。

【００３７】そして、先に示したように、周回しない線状導体のアンテナへ高周波電流を供給することと、アンテナの終端にコンデンサを挿入してインピーダンスの整合を取ることを組み合わせることにより、アンテナにかかる高周波電圧の振幅を大きく低減できる。例えば、本発明による周回しないアンテナの１実施例である図９に示すようなリング状導体のアンテナ（ダブル・ハーフループアンテナ）の場合には、後述される様に、同径で従来方式の周回する１ターンのアンテナの場合に比べてインダクタンスは１／２となる。このため、周回する１ターンのアンテナを用いてその接地側電極を直接に接地電位に接続する従来の方式に比べて、高周波電圧の対地振幅はその約１／４となる。これは、アンテナに発生する対地電圧振幅として、従来方式と同程度の電圧が許される場合、従来方式に比べて１６倍もの高出力の高周波電力を供給可能であることを示している。

【００３８】

【発明の実施の形態】図１に示した本発明装置の１実施例を説明する。本装置は直径４００ｍｍ、高さ２００ｍｍの円筒型真空容器１の内部に、アンテナ導体５として、図９に示される直径３６０ｍｍのリング電極からなる高周波アンテナ１４を容器側壁に設けた２つの導入端子８、９に固定して設置している。そして容器側壁の一方の導入端子８には、図９に示されている高周波電源（周波数：１３．５６ＭＨｚ）１２が整合器１１を介して接続されている。そしてこのリング電極の表面全てを、肉厚２ｍｍの高純度アルミナセラミックス（９９．６ａｔ％）の絶縁体チューブ６で被覆している。絶縁体の材質ならびに厚さの選択にあたっては、式（１）からも分かるように、シースの等価インピーダンスよりも十分に大きい（例えば一桁以上）インピーダンスを有する（$Z_{insulator}>>Z_{sheath}$）ことが必要であり、さらにはプラズマに直接曝されても問題を生じない耐熱性、化学的安定性、機械的強度、電気絶縁性等を有することを要件とする。このため、例えば高純度アルミナ、石英、ジルコニア等の高抵抗、高絶縁性、低誘電率を同時に満たすことが可能なセラミック誘電体群の材質で、厚みは２～４ｍｍ程度であればよい。また他方の導入端子９にはコンデンサ（静電容量：４００ｐＦ）が接続されており、このコンデンサを介して接地されている。図９に示すように導入端子は、リング状電極に対して直径線上で向かい合うように配置され、リング状電極の直径線上の２つの接続点から高周波電力を供給するような構造（ダブル・ハーフループアンテナ）になっている。この様な電力の供給方式により、同径で従来方式の周回形状を有する１ターンのアンテナの場合に比べて、アンテナのインダクタンスは半減される。本実施例に用いたリング電極（フルループ）のインダクタンスを計測した結果、約１２００ｎＨであった。そして、ダブル・ハーフループ構造にてインダクタンスを同様に計測した結果６００ｎＨが得られ、インダクタンスは半減した。

【００３９】また、容器側壁の導入フランジを用いてプラズマ計測用のラングミュアープローブを導入し、このプローブによりプラズマ状態を計測した。

【００４０】まず、真空ポンプにて真空容器内を1×10^{-4}Ｐａまで排気した後、図示していないガス導入口よりアルゴンガス（Ａｒ）を1.1 Ｐａまで導入し、高周波電力を１２０Ｗ～２４００Ｗまで投入し、真空容器内にプラズマを発生させた。この時ラングミュアープローブにより真空容器中心部（アンテナ設置面より－６５ｍｍ）のプラズマ密度を計測した。

【００４１】また、アンテナの接地側に挿入したコンデンサの効果を検討するため、コンデンサを挿入した場合（浮遊型アンテナ）とアンテナ終端を直接接地電位に接続した場合（接地型アンテナ）について実験を行い比較した。

【００４２】図６に、浮遊型アンテナと接地型アンテナそれぞれのアンテナ状態における高周波投入電力（P_{rf}）とプラズマ密度（n_p）との関係を示す。同図に見られるように、浮遊型アンテナ及び接地型アンテナ何れにおいてもP_{rf}の増加に伴いn_pは増大し、P_{rf}＝２．４ｋＷで荷電粒子密度が5×10^{11}（cm^3）の高密度プラズマが得られ、アンテナ接地状態の違いによるn_pの違いは無いことがわかる。また、本実施例で得られるプラズマ密度は、従来方式による放電室径が３００ｍｍφ以下のプラズマ発生装置で得られているものと同程度かそれより高い値となっており、本発明のプラズマ発生方式によれば、従来方式のプラズマ発生装置に比べて大口径化した場合でも実用化レベルの高密度プラズマが容易に得られることを示している。

【００４３】さらに図７には、同時にオシロスコープで計測した接地型アンテナと浮遊型アンテナそれぞれにおける高周波電圧（$V_{antenna}$）の変化を示す。接地型アンテナの場合、n_pが1×10^{11}（cm^3）以上になるP_{rf}５００Ｗ以上の領域では、P_{rf}の増加に依存して$V_{antenna}$も増大する。これに対し高周波電圧平衡条件を満たす浮遊型アンテナの場合、接地型アンテナの場合の半分かそれ以下の$V_{antenna}$値を示す。そして、P_{rf}＝２．５ｋｗの時、接地型アンテナでは$V_{antenna}$＝約１８００Ｖに対し、浮遊型アンテナでは、$V_{antenna}$＝６００Ｖと、約１／３の電圧に抑えられている。これらの結果から、アンテナの接地側に高周波電圧平衡条件を満たすコンデンサを挿入することは、プラズマ密度を低下させることなくアンテナにかかる電圧値の低減を可能にし、大電力投入による安定した高密度プラズマの生成を容易にする。

【００４４】図１の実施例と同様の装置を用いて、アルゴンガス（Ａｒ）を1.1 Ｐａまで導入し、高周波電力を１２０Ｗ～２４００Ｗまで投入し、真空容器内にプラズマを発生させた。この時アンテナの終端は直接接地電位に接続した。またこの時アンテナ表面の絶縁体被覆の効果を検討するため、アンテナ表面に絶縁体を被覆した場合としない場合について同様の実験を行って比較した。

【００４５】図８に、それぞれのアンテナ状態における高周波投入電力（P_{rf}）に対するプラズマ密度（n_p）の変化を示す。絶縁体被覆無しのアンテナ状態の場合、P_{rf}＝５００ＷまではP_{rf}の増加に依存してプラズマ密度（n_p）は増加する。しかしP_{rf}＝５００Ｗ以上になると真空容器内の至る所（例えば、導入端子部）で異常放電が多発し、安定したプラズマを得ることができなかった。これはプラズマ密度の増加に伴いプラズマ電位が急激に上昇し、その結果、真空容器内の各所で異常放電が生じたと考えられる。

【００４６】一方、絶縁体で被覆したアンテナではP_{rf}の増加に対し異常放電を起こすことなくn_pは増加し、P_{rf}＝２．４ｋｗで5×10^{11}（cm^{-3}）の高密度プラズマが安定して得られている。これは、アンテナ表面を絶縁体にて被覆したことにより、プラズマからアンテナに流入する電子が遮断され、その結果プラズマ電位の上昇が抑制されたことに起因すると考えられる。この様に、アンテナ表面を絶縁体で被覆することにより安定した高密度プラズマが得られることが明らかになった。

【００４７】図９は、リング状の導体を用いたアンテナの実施例を示す。図中、１３は円筒状の真空容器で、断面を示したもの、１４は真空容器１３の内壁に沿って配置されたリング状導体からなる高周波アンテナである。リング状導体の任意の直径線についてその2 つの端点に駆動側の接続点と接地側の接続点が設定される。高周波アンテナ１４は、これら２つの接続点で２つの対称な半円形線状導体の枠を並列接続した構造を持つ。駆動側の接続点には、整合器１１を介して高周波電源１２から高周波電流が供給され、接地側の接続点と接地との間には、ブロッキングコンデンサ７が挿入されている。

【００４８】図１０および図１１は、図３に示す装置の変形実施例を示したものである。

【００４９】図１０の実施例における高周波アンテナ１６は、図３に示されている全体が矩形の枠状の高周波アンテナ１０の内側に複数本の直線状導体を柵状に配設したものであり、図９の実施例の場合と実質的に同じ機能をもつが、高周波電流を複数の直線状導体に並行して流せるため、特に断面が矩形の真空容器１５内で高密度プラズマ生成を行うのに有効である。

【００５０】また図１１に示す実施例は、複数の直線状アンテナ１８ａ～１８ｆを、真空容器１７の内壁面に沿って縦方向か横方向、あるいは２次元状に配置したマルチ型直線状アンテナである。各直線状アンテナ１８ａ～１８ｆは真空容器１７の外側で並列接続され、整合器１１とブロッキングコンデンサ７が接続される。図１１の実施例はマルチ型直線状アンテナである点を除けば、図９の実施例の場合と実質的に同じ機能をもつが、特に大口径で長軸の真空容器内での高密度プラズマ生成を行うのに有効である。なお必要に応じて、各直線状アンテナ１８ａ～１８ｆをコの字形あるいは円弧形のアンテナに変更することも可能である。

【００５１】また図１、図３、図９、図１０、図１１などの実施例において、真空容器の外壁に沿いマルチカスプ型の永久磁石を取り付けるなど、適当な磁界発生手段を付加することによって、プラズマ密度の一様性をさらに向上させることができる。

【００５２】

【発明の効果】本発明では、プラズマ生成用のアンテナ自体を真空容器内に設置しているため、放電室の形状や口径および長さに制限されることがない。またアンテナ導体の表面を全て絶縁体で被覆することにより、大口径かつ大容積の高密度プラズマを安定して生成することが可能になる。

【００５３】さらに本発明では、アンテナの大型化に伴うインダクタンスの増加を抑制するため、周回しない線状の導体をアンテナに用い、加えてアンテナの終端と接地との間に電気容量が固定または可変のコンデンサを挿入して整合させることにより、高密度でプラズマ電位の低いプラズマが生成されるため、ダメージの少ないプラズマ処理を実現可能にすると共に、異常放電を発生させることなく大電力の高周波電力を供給できるため、プラズマの高密度化を図ることが容易である。

【図面の簡単な説明】

【図１】本発明の基本構成説明図である。

【図２】アンテナ導体を絶縁体で被覆した場合の等価回路図である。

【図３】周回しないアンテナ形状の１例の構成図である。

【図４】接地型アンテナと浮遊型アンテナの等価回路図である。

【図５】接地型アンテナと浮遊型アンテナの電圧分布説明図である。

【図６】接地型アンテナと浮遊型アンテナにおける高周波投入電力とプラズマ密度の関係を示すグラフである。

【図７】接地型アンテナと浮遊型アンテナにおける高周波電圧の変化を示すグラフである。

【図８】アンテナ表面の絶縁体被覆の効果を示すグラフである。

【図９】リング状の導体を用いたアンテナの実施例構成図である。

【図１０】柵状の導体を用いたアンテナの実施例構成図である。

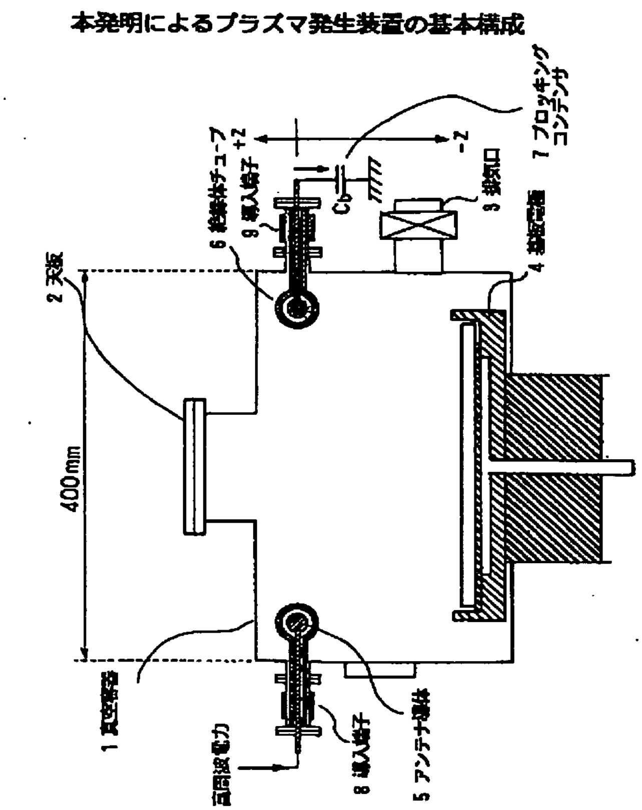
【図１１】複数の直線状導体を用いたアンテナの実施例構成図である。

【図１２】従来のＩＣＰを用いたプラズマ処理装置の１例を示す構成図である。

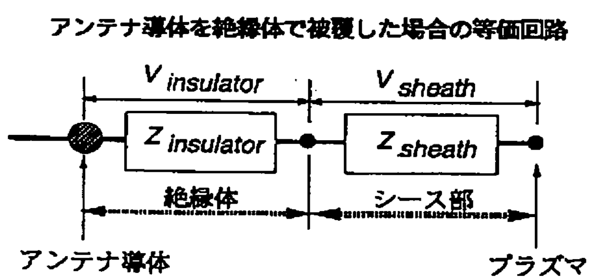
【符号の説明】

１：真空容器
２：天板
３：排気口
４：基板電極
５：アンテナ導体
６：絶縁体チューブ
７：ブロッキングコンデンサ
８、９：導入端子

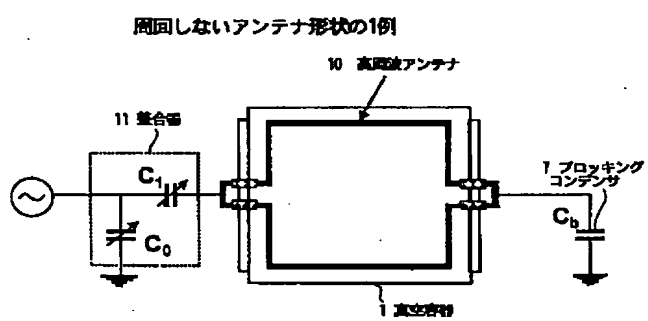
【図１】



【図２】

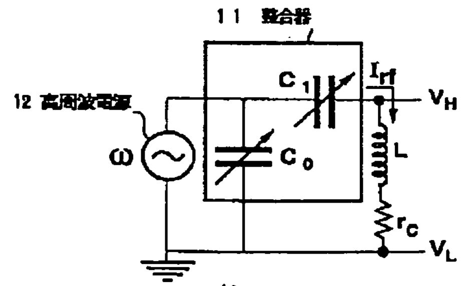


【図３】

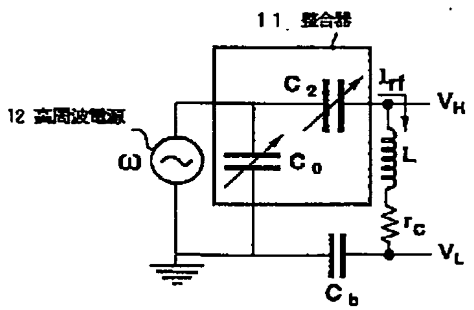


【図４】

接地型アンテナと浮遊型アンテナの等価回路



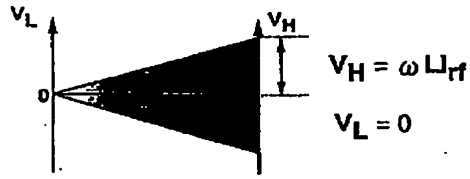
(a) 接地型アンテナ



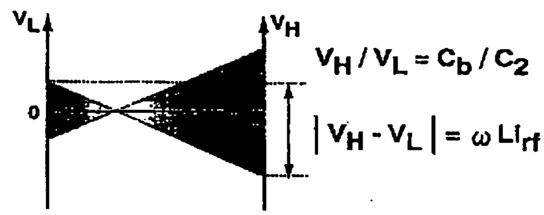
(b) 浮遊型アンテナ

【図５】

接地型アンテナと浮遊型アンテナの電圧分布



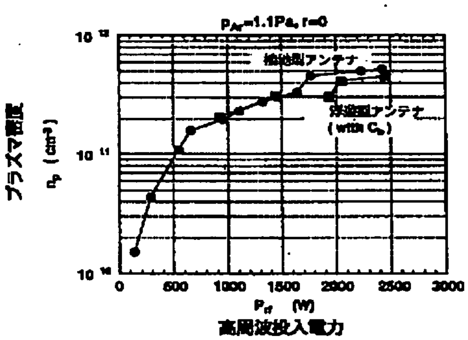
(a) 浮遊型アンテナ



(b) 接地型アンテナ

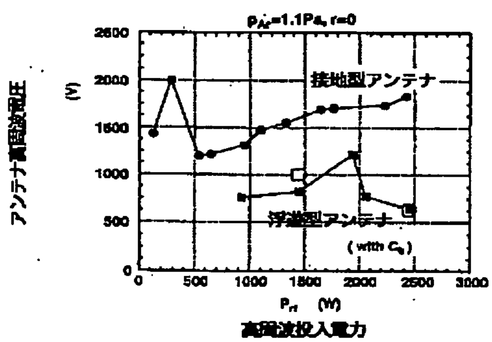
【図６】

接地型アンテナと浮遊型アンテナにおける
高周波投入電力とプラズマ密度の関係



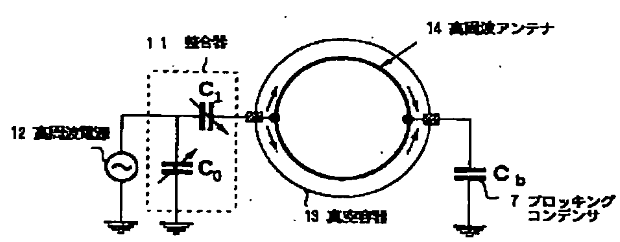
【図７】

接地型アンテナと浮遊型アンテナにおける
高周波電圧の変化

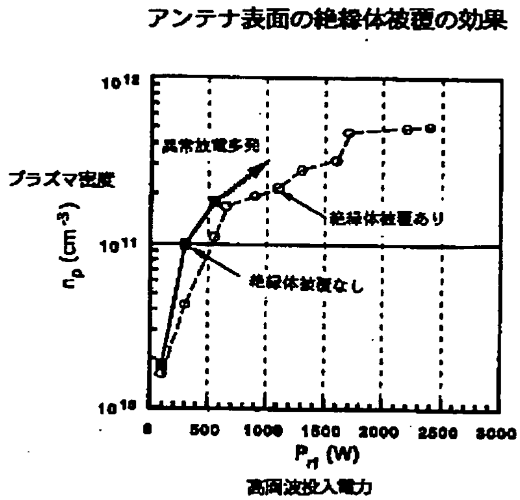


【図９】

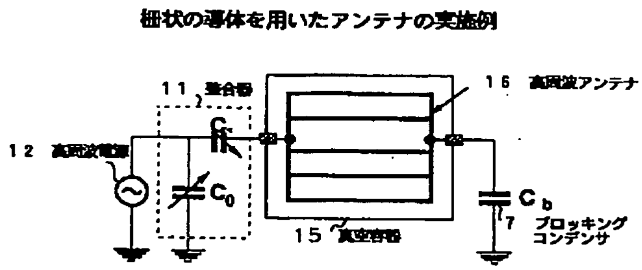
リング状の導体を用いたアンテナの実施例



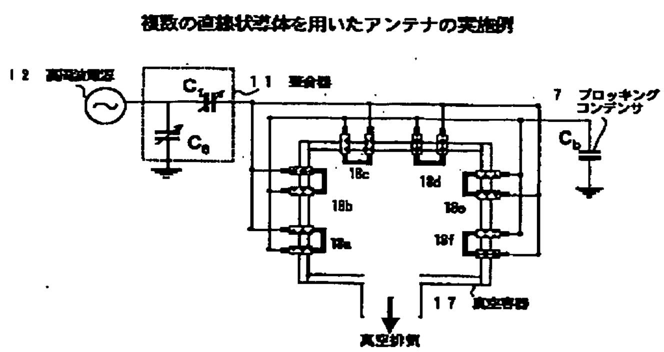
【図８】



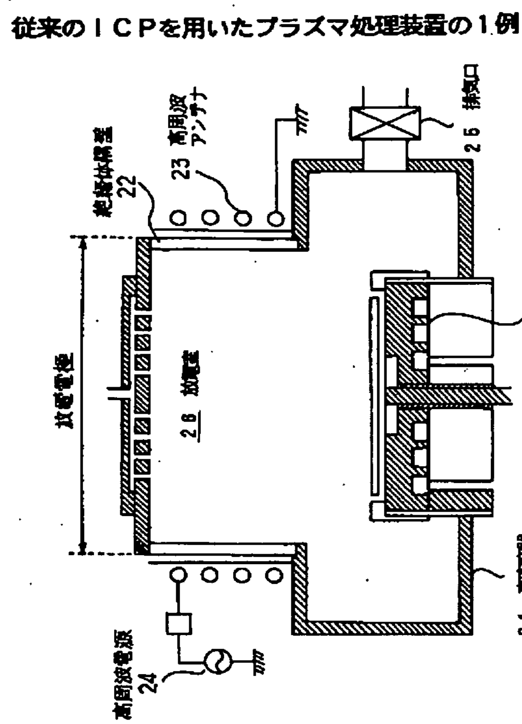
【図１０】



【図１１】



【図１２】



フロントページの続き

Ｆターム(参考)　5F004 AA06 AA16 BA20 BB11 BB18
BB23 BB30 BC08 BD01 BD04
DA23